Integrating HEC Tools in Shared Vision Planning

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Models Models Models

- Shared Vision Planning relies on technical models
- Custom-built models have been the default because:
  - No hidden assumptions – No black boxes
  - Can accommodate all interests and perspectives – No limitations
  - Collaborative development and validation builds trust, promotes collaborative learning, and catches errors
- Downside is
  - Need to build from scratch
  - May engender dueling models (ACT-ACF)

Can we take the best of both worlds?

- Established models (e.g. HEC tools) already
  - May be widely accepted in the study area
  - Already be calibrated to the system of interest
  - May be required by regulation, policy, or to satisfy stakeholders
  - Have had some level of de-bugging and testing
  - Are getting more and more user-friendly
- Challenge is to adapt both the existing model to the SVP process, and the SVP process to be able to use the Established model

Issues

- Level of detail, resolution, and data needs in an established model may not be consistent with the planning problem at hand.
- Options
  - Run the established model real-time within the more inclusive, systems dynamics model
  - Dumb down the established model and incorporate it to run real-time within a more inclusive systems dynamics model
  - Recode the dynamics from the established model to recreate results of established model and seamlessly exchange results from the systems dynamics model to the established model
  - Something in between

Current Initiatives

- Lake Ontario – some models recoded in Stella, others used Stella output. Excel post-processor integrated models.
- Middle Rio Grande – USGS ground water model (MODFLOW) wrapped to transfer results between established model and systems dynamics representation
- Willamette River (starting) – will link HEC-ResSim as well as CE-QUAL2E
- Mississippi Headwaters (ROPE) – using optimization output as well as penalty function input in simulation and post-processor models.

Outline

- Roles of Simulation and Optimization
- Articulating Objectives to an Optimization Model
  - roles of stakeholders and experts
  - use of detailed models
- Penalty curve units
  - monetary vs non-monetary
- Example of developing penalty curves
- Collaborative use of Simulation and Optimization

Two Approaches to Modeling

- The Mississippi Headwaters ROPE study uses a simulation model and an optimization model
  - A simulation model makes decisions that follow operating rules specified by the user
  - An optimization model makes decisions by maximizing the benefit achieved by various objectives "described" by the users

    HEC is using the Prescriptive Reservoir Model (PRM) to perform optimization analysis for ROPE

Tasks of the Models

- The task of a simulation model is to answer “what if” questions
  - The model “operates” the water system for an historical period with various sets of proposed operating rules
- The tasks of an optimization model are to:
  - evaluate and quantify the tradeoffs between various objectives, and
  - seek operations (and operating rules) that achieve a desired balance between those objectives

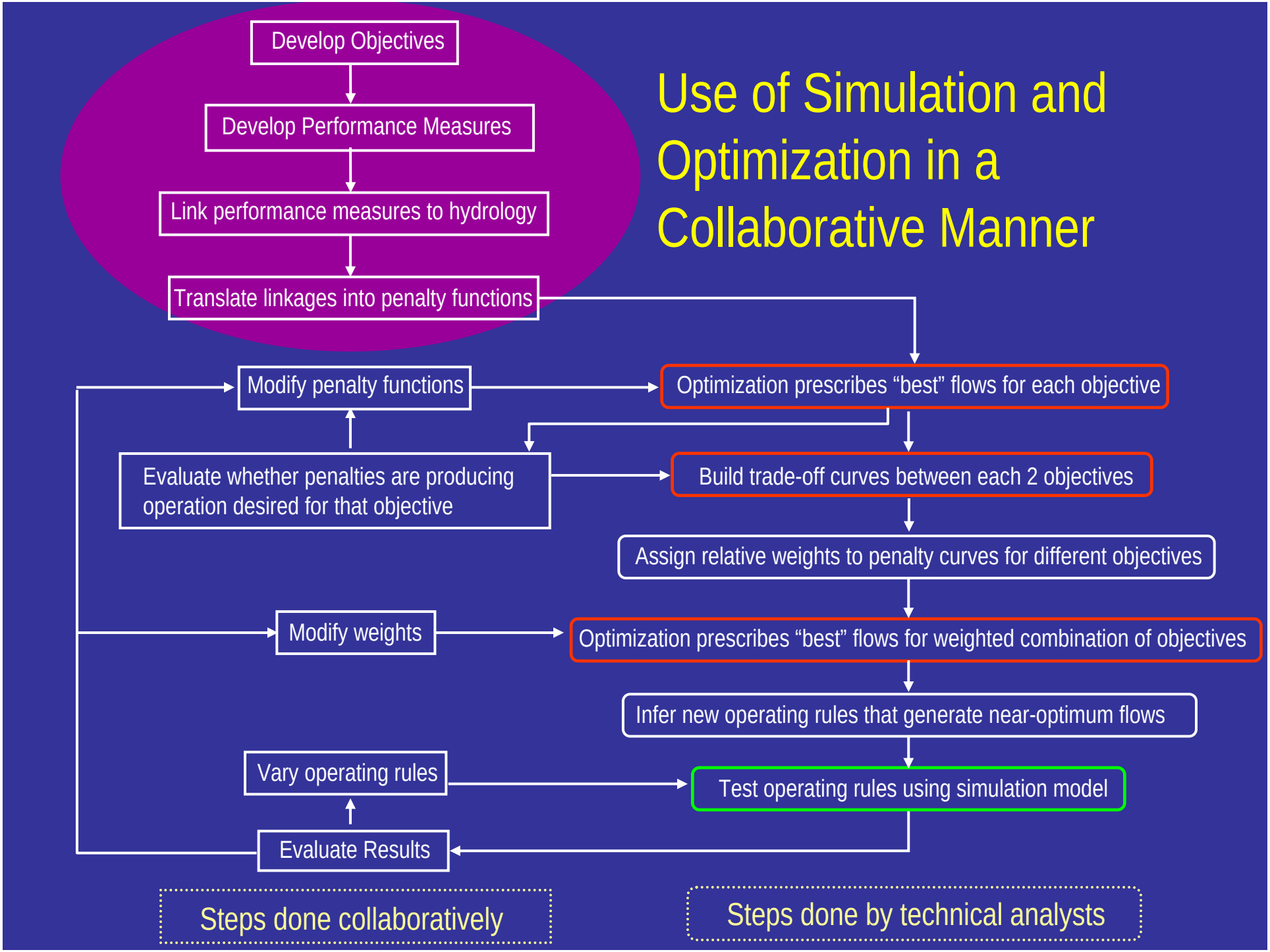
Use of Optimization AND Simulation

- Optimization and Simulation models play a complementary role in developing operating rules
  - Optimization models make decisions that maximize benefit, but decisions can't be reproduced in real-time
    - Must infer operating rules that approach those optimal operations (determined with perfect foresight…)
  - Simulation models demonstrate the outcome of proposed rules, and allow adjustments to target the outcome achieved by the optimization

How Optimization Works

- Focused on maximizing the OBJECTIVES of system operations as defined by stakeholders
- No previously defined rules -- don't tell the system how to achieve the objectives
- Stakeholders and experts articulate the system objectives by defining a series of penalty curves
  - this is how we tell the model what is good, and for whom
  - *a "Shared Vision" collaborative exercise*

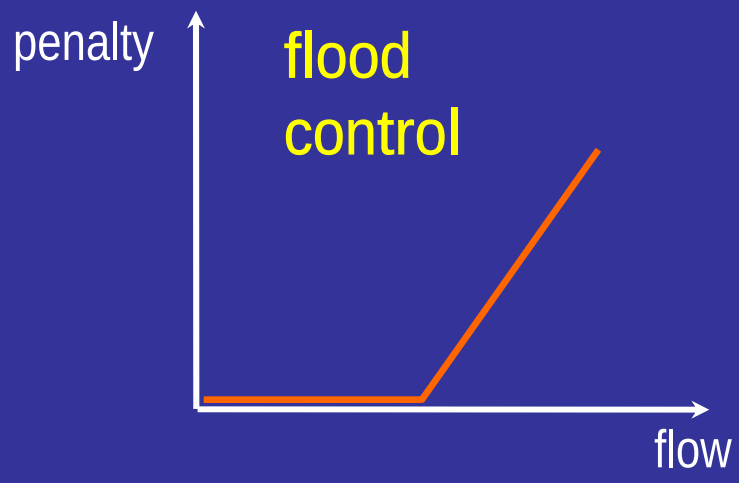
Use of Simulation and Optimization in a Collaborative Manner

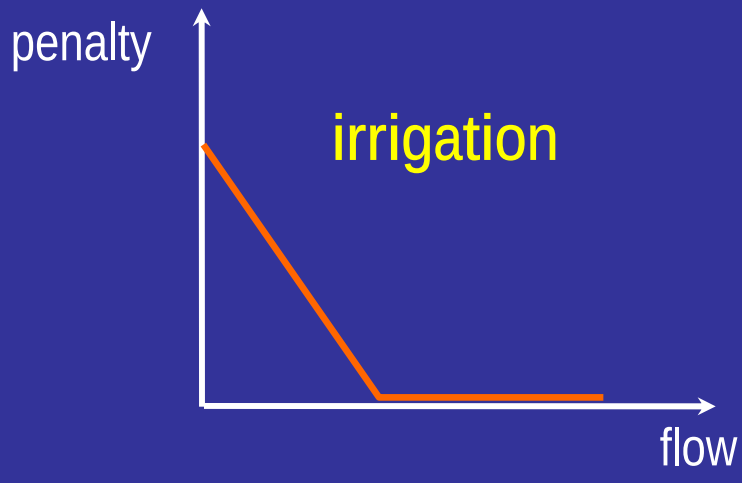


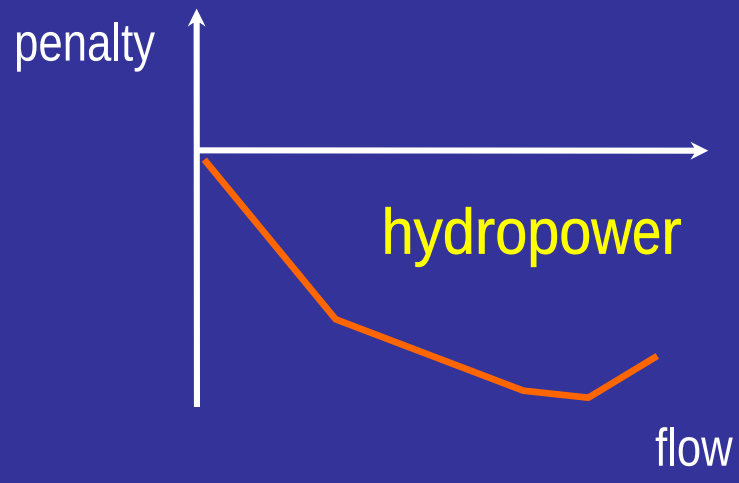
Articulating Objectives

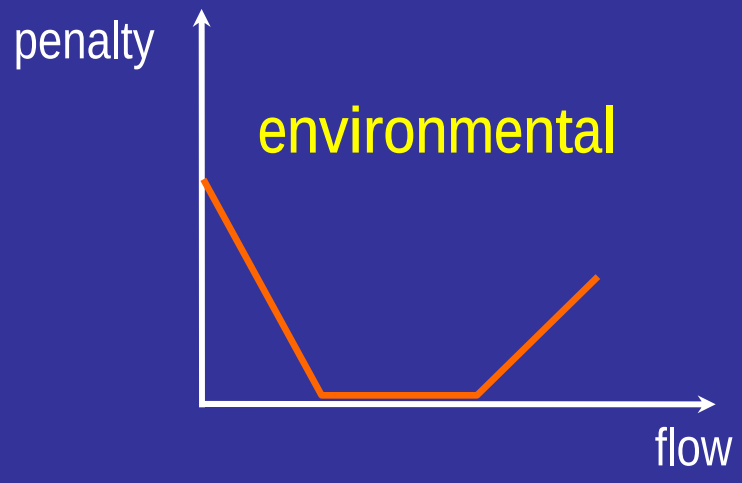
- We can articulate our objectives and goals using penalties (or benefits)
  - these penalties are used both to “drive” the optimization and evaluate performance in simulation results
- Penalties are applied for detrimental occurrences
  - flow that causes flood damage, reservoir elevation outside recreation range
- Negative penalties (benefits) are applied for positive occurrences
  - streamflow available for habitat, irrigation, hydropower

Examples of Penalty Curves









Objectives at each site in Mississippi Headwaters ROPE

Node No.	Node Description	Flood Control & Drawdown	Hydro-power	Erosion Control	Recreation	Environ-mental For Lake Stages	Environ-mental For River Discharge	Tribal Interest	Navigation, Waste Assimilation, and Water Supply
1	Bemidji /Irving Lakes		X	X	X	X	X		
2	Wolf Lake			X	X	X			
3	Andrusia & Big Lakes			X	X	X		X	
4	Cass Lake	X		X	X	X	X	X	
5	Winnibigoshish Lake	X		X	X	X	X	X	
6	Little Winni Lake			X	X	X		X	
7	Leech Lake	X		X	X	X	X	X	
8	Big Boy Lake	X		X	X	X		X	
9	Mud & Goose Lakes				X	X	X	X	
10	Confluence Miss & Leech Rivers	X		X	X		X	X	
11	Confl. Miss & Ball Club Rivers	X		X	X		X	X	
12	Ball Club Lake	X		X	X	X		X	
13	White Oak Lake	X		X	X	X		X	
14	Little White Oak Lake	X		X	X	X		X	
15	Days High Landing Gage	X	X	X	X		X	X	
16	Pokegama Dam and Lake			X	X	X	X	X	X
17	Blandin Dam at Grand Rapids		X		X	X			
18	Lawrence Lake	X		X	X	X			
19	Prairie Lake and Dam		X	X	X	X		X	
20	Confl. Miss & Prairie Rivers	X	X		X		X	X	
21	Miss near Sandy Lake	X	X	X	X		X	X	
22	Big Sandy Lake	X		X	X	X	X		

Where do penalty curves come from? Collaboration….

- "Task Force" can use more-detailed modeling to express how a given objective benefits or suffers from each level of flow or reservoir elevation
  - flood damage
    - hydraulic model develops stage/flow relationship
    - structure inventory relates stage to # structures affected and dollar damage
  - environmental
    - env. model translates flow into suitable habitat measures
- What units? – penalty units are not important

Monetary or Non-monetary Penalties

- Values and Penalties can be monetary
  - flood damage, price of water, hydropower
- Or, when value cannot be captured in dollars, non-monetary
  - environmental uses – acres of habitat, spawning area
  - recreation – user-days
- We can also set unit-less penalties to encourage an operating preference that can't be articulated
  - referred to as "persuasion penalties"

Example: Penalties for Recreation

- One reasonable unit of measurement is reservoir usage in visitors per month
- If have some data on reservoir usage as a function of elevation, can use it directly
- Otherwise, perhaps relate usage to facilities available at any elevation…

Availability and Usage of Docks

Elev (ft)	Docks available
511	0 docks available
522	¼ docks available
528	¾ docks available
532	¼ docks available
540	0 docks available
545	

Season	Usage per ¼ of docks
Summer	600 visitors/month
Fall	200
Winter	20
Spring	350

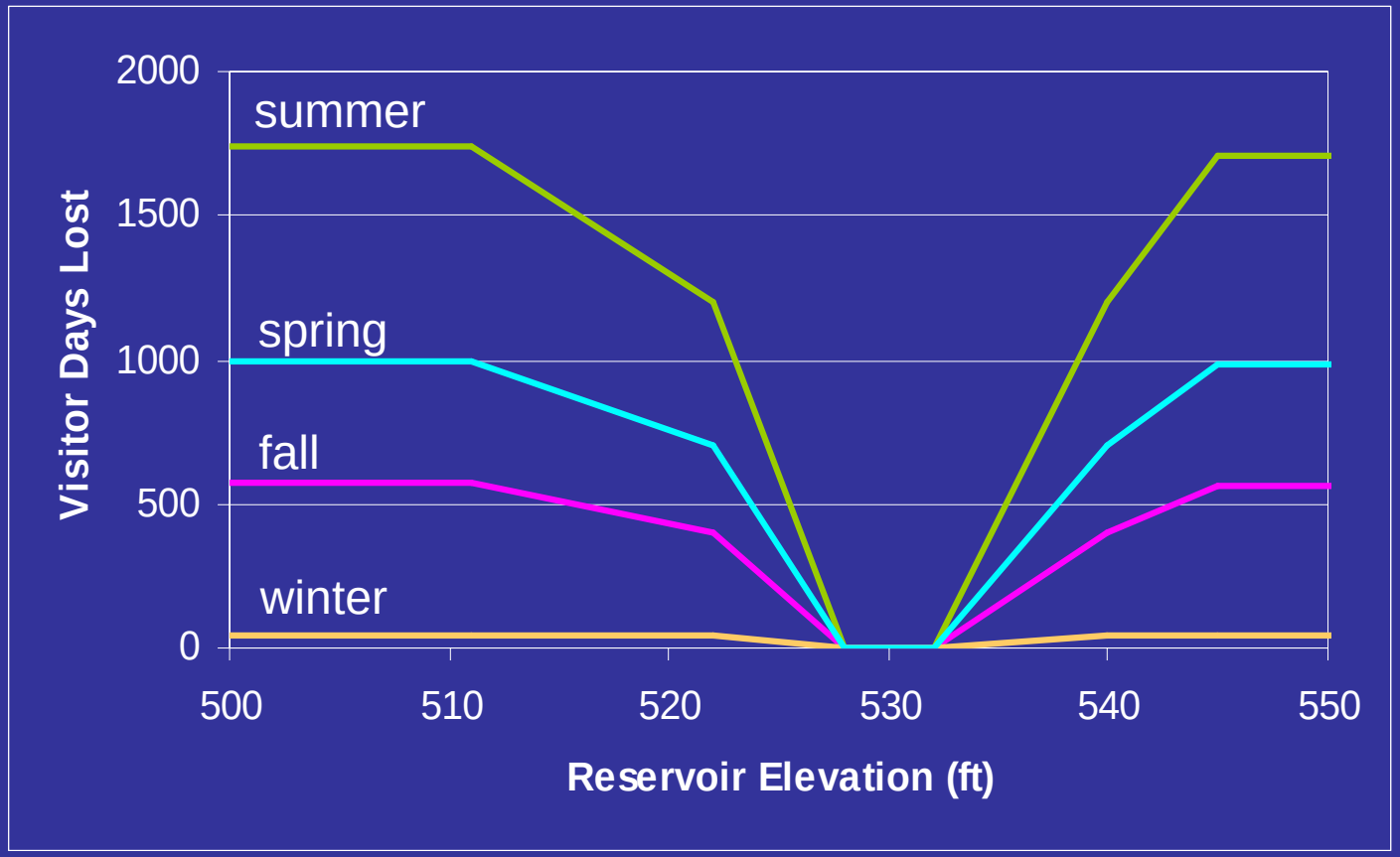
Additional usage unrelated to dock-availability

Season	below docks	above docks
Summer	60	90
Fall	30	40
Winter	20	20
Spring	50	70

Usage as Function of Elevation

Elevation	Summer	Fall	Winter	Spring
	values in visitors per month			
511	60	30	20	50
522	600	200	20	350
528	1800	600	60	1050
532	1800	600	60	1050
540	600	200	20	350
545	90	40	20	70

Usage as Function of Elevation



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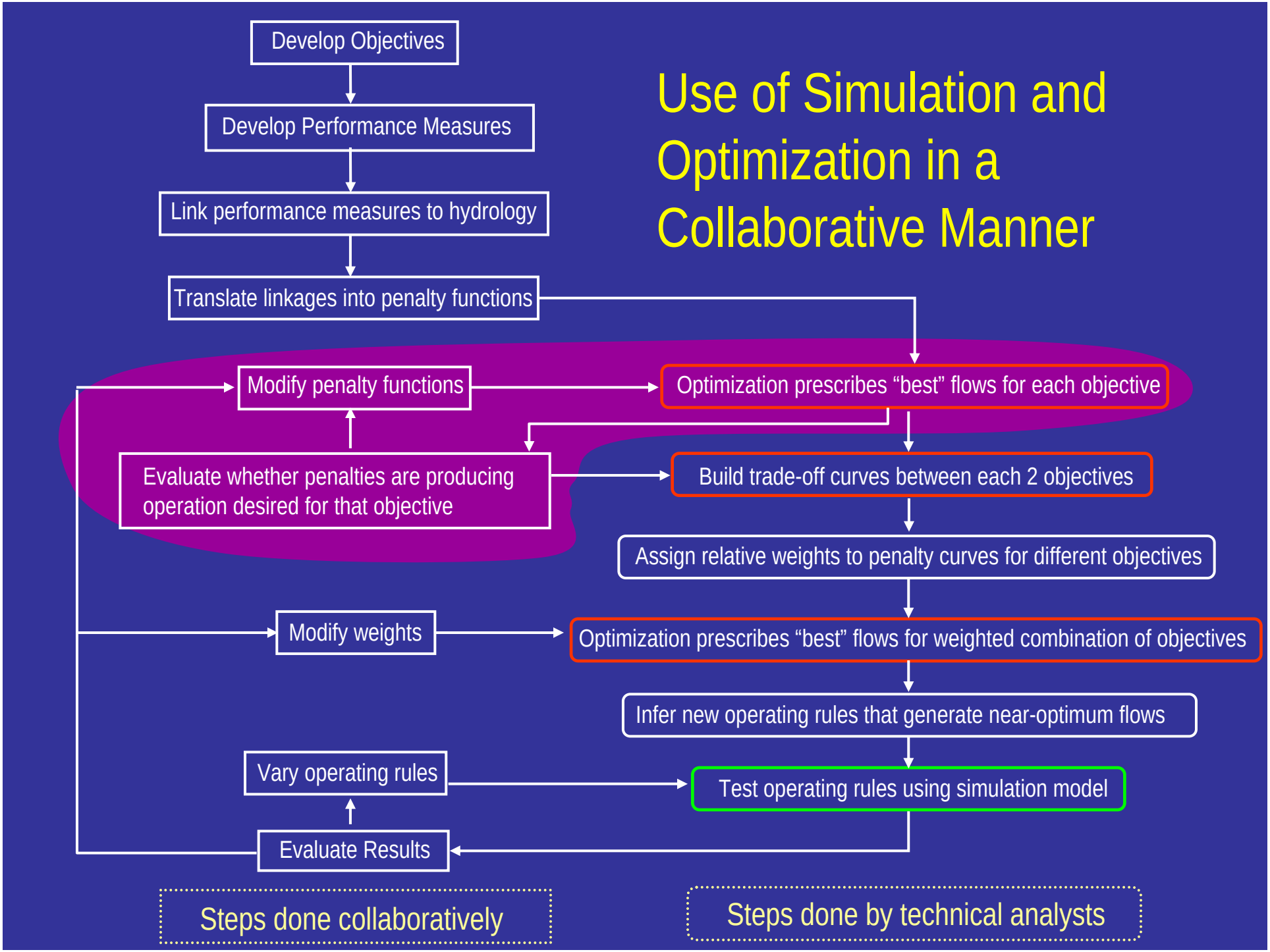
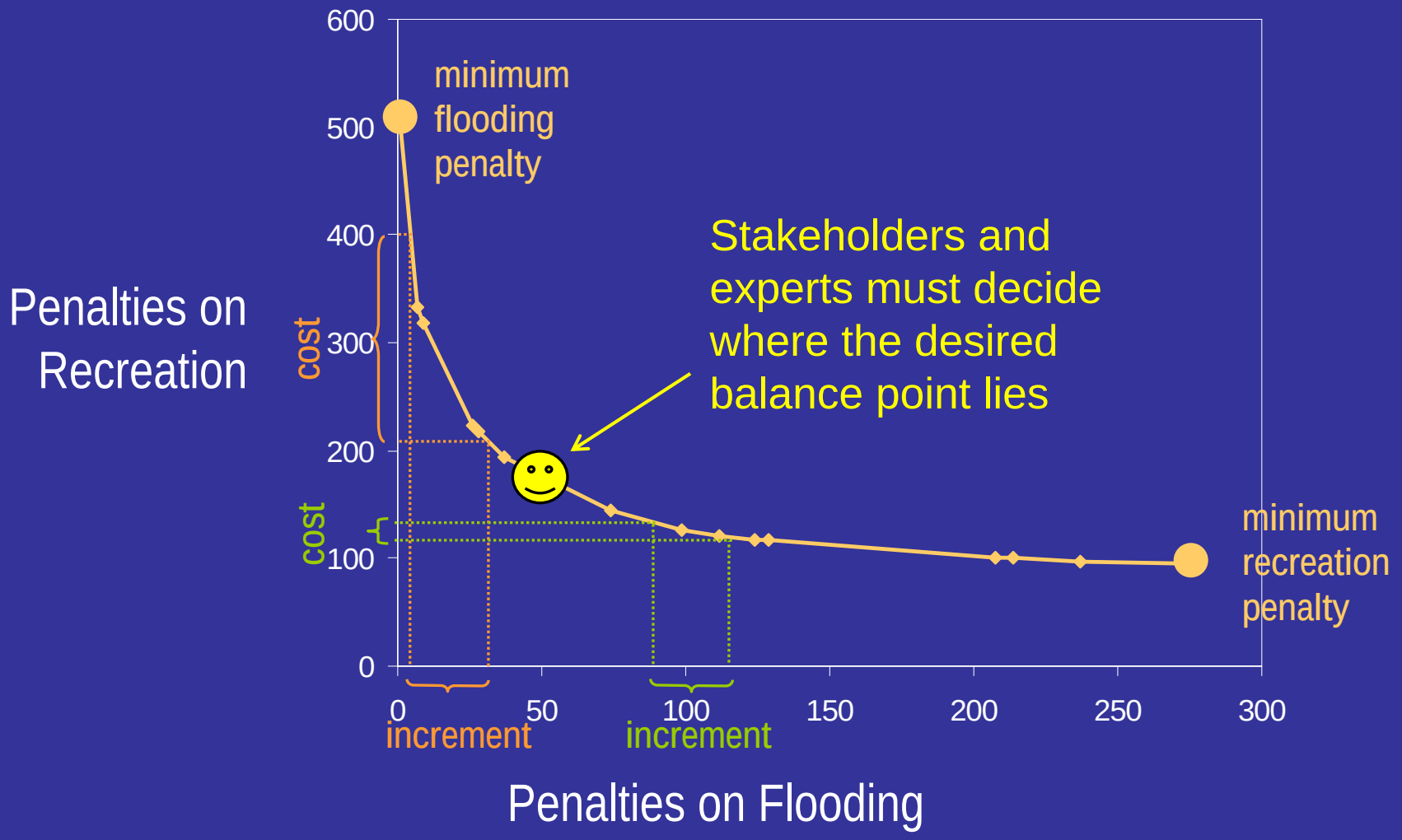
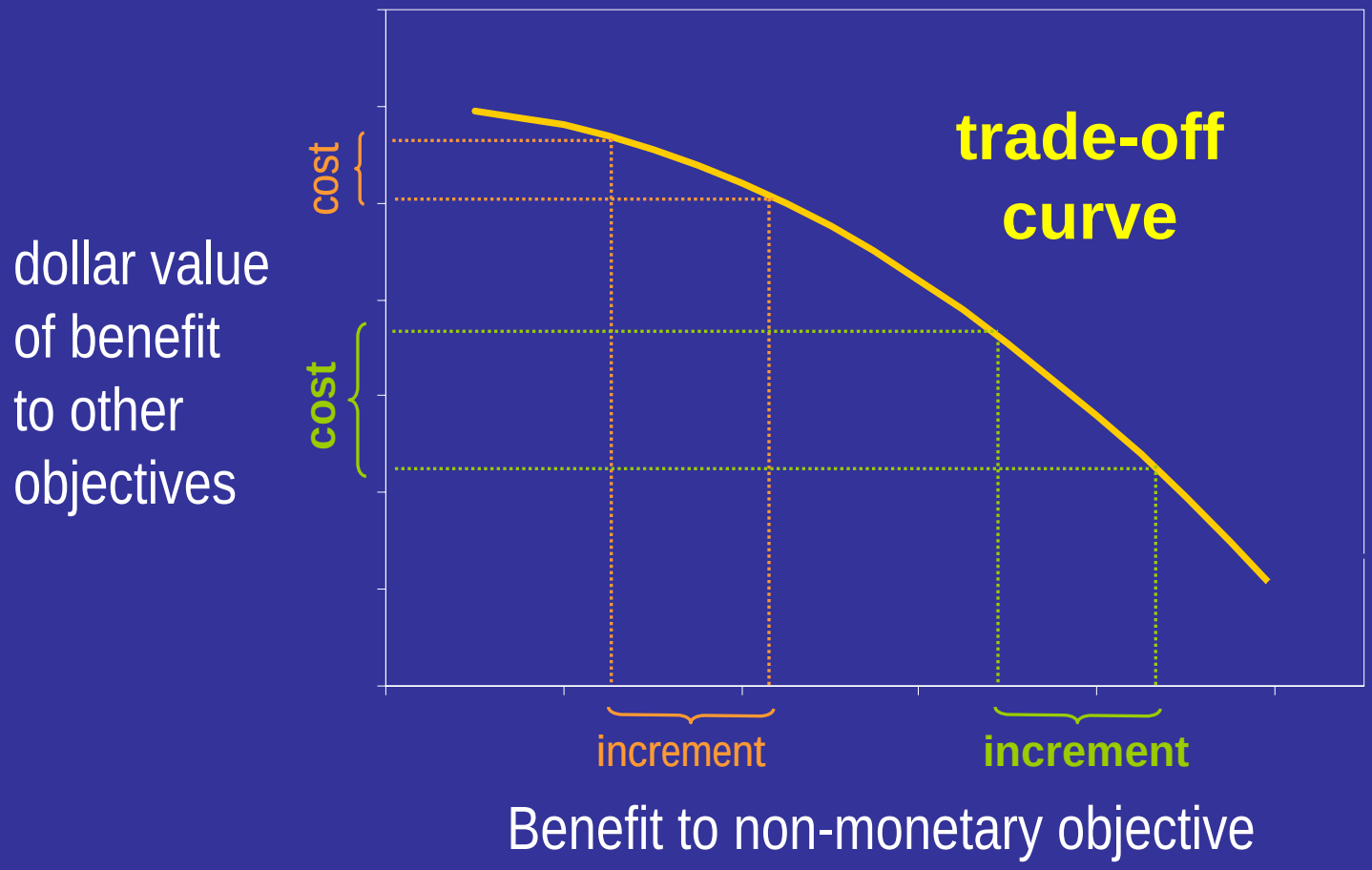


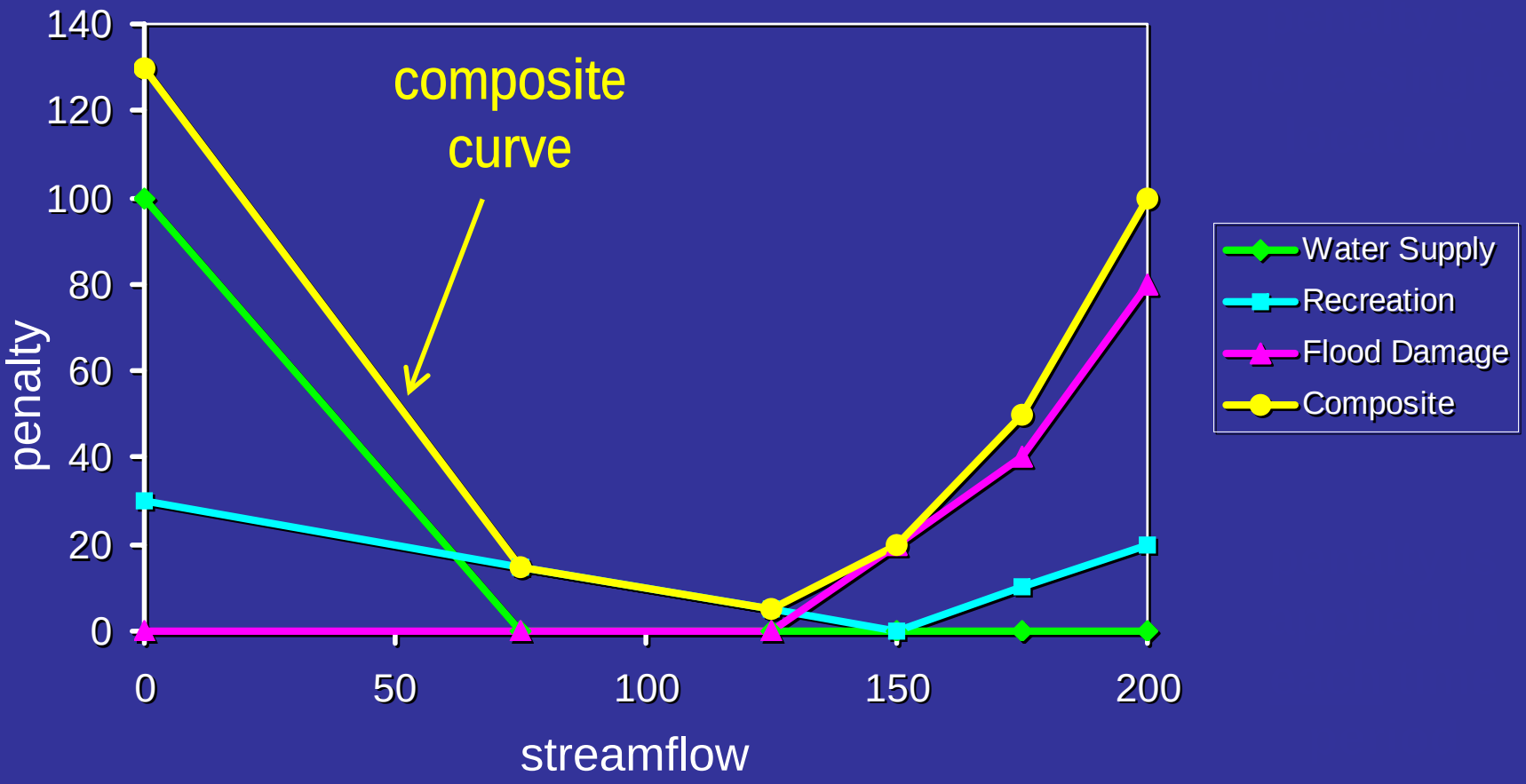
Flood vs Recreation Trade-off Curve



Comparing Monetary to Non-Monetary Objectives



Combined Penalty Curves



Prioritizing Objectives?

- If one objective is more important than another, can give it a higher priority
  - in the optimization, it would be satisfied first
- Sometimes vary priorities to determine the system's sensitivity to these assumptions

“Fairness” as an Objective

- Standard network optimization maximizes the NET of all benefits or minimizes the NET of all penalties
  - Assumes optimum net is the GOAL
- However, sometimes the net should be sacrificed to achieve fairness or equal hardship to all parties…
- Can instead minimize the maximum hardship to any party